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Anopheles prachongae, a new species of the Gigas Complex of subgenus *Anopheles* (Diptera: Culicidae) in Thailand, contrasted with known forms of the complex

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Abstract

Anopheles (*Anopheles*) *prachongae*, a new species of the Gigas Complex from northern Thailand, is described and illustrated in the adult, pupal and larval stages, and bionomics and chaetotaxy tables are provided for the immature stages. The species is distinguished from *Anopheles baileyi*, the only other species of the complex known to occur in Thailand, and contrasted with other taxa of the complex that occur in the Oriental Region. Available morphological data indicate that *An. gigas sumatrana* is unique and is therefore formally afforded species status. The three other Sumatran subspecies may be conspecific. The taxonomic status of the non-Sumatran subspecies, *i.e. crockeri* (Borneo), *formosus* (Philippines), *refutans* (Sri Lanka) and *simlensis* (south-central Asia), is questioned but their status is unchanged pending further study.

Key words: *Anopheles*, *baileyi*, mosquito, *prachongae* **n. sp.**, taxonomy, systematics

Introduction

Giles (1901) described *Anopheles gigas* from adult males and females collected at an elevation of 6,000 feet (1828.8 m) in the Nilgiri Hills of southwestern India. Between 1909 and 1954, eight "varieties" of *An. gigas* were described from mountainous localities in the Oriental Region, including *formosus* Ludlow, 1909 (Philippines), *simlensis* James, 1911, in James & Liston (1911) as a species of genus *Patagiamyia* (India), *refutans* Alcock, 1913 (Sri Lanka), *sumatrana* Swellengrebel & Rodenwaldt, 1932 (Sumatra), *danaubento* Mochtar & Walandouw, 1934 (Sumatra), *oedjalikalah* Nainggolan, 1939 (Sumatra), *pantjarbatu* Waktoedi Koesoemawinangoen, 1954 (Sumatra) and *baileyi* Edwards, 1929 (Tibet). Colless (1955) described a subspecies, *An. gigas crockeri*, from northern Borneo (Sabah, Malaysia). Although the eight nominal varietal forms were treated as subspecies at one time or another in various publications, Stone *et al*. (1959) and Knight & Stone (1977) treated them as varieties as originally proposed. Thus, Knight & Stone (1977) listed 10 forms of *An. gigas*, including the nominotypical form, eight varieties and one subspecies, in their catalog of the Culicidae. Harrison *et al*. (1991) subsequently elevated var. *baileyi* to species status, thus leaving seven formally designated varieties. Applying provisions contained in Article 45 of the *International Code of Zoological Nomenclature* (International Commission on Zoological Nomenclature, 1999) that regulate the rank of species-group names, Harbach & Howard (2007) showed that the seven varieties must be afforded subspecific status. Hence, prior to this report, the Gigas Complex included two species, *An. baileyi* and *An. gigas*; the latter comprising eight geographic subspecies, *i.e. danaubento*, *formosus*, *gigas*, *oedjalikalah*, *pantjarbatu*, *refutans*, *simlensis* and *sumatrana*.

Anopheles gigas was recorded in Thailand by Barnes (1923) with uncertainty as variety *formosus*, by Thurman (1959) as variety *sumatrana* based on specimens collected between 1950 and 1956, and by Stojanovich & Scott (1966) as subspecies *baileyi*, which they included in a list and illustrated key to the *Anopheles* of Thailand. The first two records were considered doubtful by Peyton & Scanlon (1966), Scanlon *et al*. (1968) and Rattanarithikul

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& Harrison (1973). In the absence of specimens for study, the restriction of *formosus* to the Philippines (Reid, 1968) and the restriction of *sumatrana* to Sumatra, Indonesia (Bonne-Wepster & Swellengrebel, l953; Reid, 1968), Harrison & Scanlon (1975) excluded *gigas* from their revision of the *Anopheles* (*Anopheles*) of Thailand. *Anopheles gigas* was listed as absent in Thailand by Apiwathnasorn (1986), but the following year Tsukamoto *et al*. (1987) recorded the collection of *gigas sensu lato* on Doi Inthanon, Thailand's highest mountain located in Chiang Mai Province. More detailed study of specimens collected on the same mountain in 1978 and 1981 led Harrison *et al*. (1991) to identify the taxon as *gigas baileyi*, which, as noted above, they elevated to species status.

Based on the examination of type specimens of *An. gigas s.s.*, *An. baileyi* and *An. gigas* spp. *simlensis*, ssp. *refutans* and spp. *crockeri* in the Natural History Museum, London, review and comparison of published descriptions and the distributions of all forms of the Gigas Complex (references listed above), we recognize and herein formally name and describe a new species of the complex from Thailand. The new species is distinguished, in particular, from *An. baileyi*, the only other member of the complex known to occur in Thailand.

Material and methods

Specimens of the new species described below were reared individually from larvae to provide adults with associated larval and pupal exuviae. Adults were studied using stereomicroscopy and emulated natural light (daylight). Larval and pupal chaetotaxy and dissected male genitalia were studied using differential interference contrast optics. Images of wings were taken with a Canon EOS 550D digital camera mounted on a Leica M125 Stereo Microscope and images of the male genitalia and larval and pupal structures were taken with the same type of camera mounted on a Zeiss Axioskop 20 compound microscope; Helicon Focus version 3.03 software (Helicon Soft Ltd, Kharkov, Ukraine) was used to obtain extended-focus images. The morphological terminology used herein is defined in the Anatomical Glossary of the Mosquito Taxonomic Inventory (http://mosquito-taxonomic-inventory.info/). The symbols ♀, ♂, L, Le and Pe used in the *Specimens examined* section represent female(s), male(s), fourth-instar larvae, larval exuviae and pupal exuviae, respectively. Measurements (e.g. length of pupal paddle) and counts (e.g. number of setal branches) are given as a range followed by the mean or mode, respectively, in parentheses.

Anopheles (*Anopheles*) *prachongae* Rattanarithikul & Harrison, n. sp.

Anopheles **n. sp.** near *An. gigas* of Rattanarithikul *et al*., 2006 (Thailand, ♀* L* keys, larval habitats).

Diagnosis. *Anopheles prachongae* is very similar to other members of the Gigas Complex. Females resemble the other members in having basal, humeral, presector, subcostal and apical pale spots on the costal vein of the wings (a preapical pale spot is only present on the costa of *An. gigas simlensis*). Combinations of characters that distinguish females of *An. prachongae* and the other members of the Gigas Complex are contrasted in Table 1. Morphological differences of the larval and pupal stages are contrasted in Table 2. Features that distinguish *An. prachongae* and *An. baileyi*, the only members of the Gigas Complex known to occur in Thailand, are contrasted in Table 3.

Female. A fairly large brown mosquito with conspicuously spotted wings and narrowly banded tarsi. *Head*: Vertex largely with erect brown scales, with well-marked patch of erect pale scales before interocular space; interocular space with pale setae and narrow pale scales. Antenna about 0.75 length of proboscis; pedicel with mixture of brown and paler scales on mesal, dorsal and lateral surfaces; flagellomere 1 with mesal patch of brown and paler scales, other flagellomeres without scales. Proboscis length about 2.7 mm, about 1.1 length of forefemur, entirely dark-scaled, slightly shaggy in proximal 0.5, labella also dark. Maxillary palpus slightly shorter than proboscis, dark-scaled with hint of pale scales dorsally at apices of palpomeres 3 and 4, palpomere 5 entirely dark-scaled, palpomeres 1 and 2 particularly shaggy. *Thorax*: Scutum brown laterally, with broad central pale longitudinal stripe consisting of silvery white tomentum and fine golden setae; anterior promontory with erect brownish pale scales medially; scutellum with golden piliform scales along bases of large golden setae in a complete transverse posterior row. Paratergite, mesopostnotum and postpronotum bare. Antepronotum with golden

TABLE. 1. Comparison of morphological characteristics of adult females of the Gigas Complex. Sumatran forms are highlighted in pale gray. Apparent diagnostic features are in larger boldface type.

Taxon	Type locality	Maxillary palpus, apex	Wing, costa, basal dark spot	Wing, preapical pale spot	Wing, R_{4+5} – M_{3+4} pale fringe spots	Wing, pale fringe spot between tips of 1A and CuA	Wing, pale fringe spot between tips of CuA and M_{3+4}	Wing, anal vein, distal pale spot	Midfemur, dorsal preapical pale spot
An. baileyi	Tibet	Dark	Short	Present on R_1	Absent	Absent	Absent	Absent	Present
An. prachongae	Thailand	Dark	Long	Present on R_2	Present	Absent	Absent	Present	Present
An. gigas									
ssp. *crockeri*	Borneo (Sabah)	Dark	Long	Absent	Present	Present	Absent	Present	Absent
ssp. *danaubento*	Sumatra	Pale	Long	Present on R_1-R_2	Absent	Present	Absent	Present	Absent
ssp. *formosus*	Philippines	Pale	Short	Present on R_2	Absent	Present	Absent	Present	Absent
ssp. *gigas*	India	Dark	Long	Absent	Present	Present	Absent	Present	Absent
ssp. *oedjalikalah*	Sumatra	Pale	Long	Present/absent on R_2	Absent	Present	Absent	Present	Absent
ssp. *pantjarbatu*	Sumatra	?	?	?	?	?	?	?	?
ssp. *refutans*	Sri Lanka	Sometimes pale	Long?	Absent?	Absent	Present	Absent	Present?	Absent
ssp. *simlensis*	India	Dark	Short	**Present on costa** and R_1	Present*	Present	Absent	Absent	Present
ssp. *sumatrana*	Sumatra	Dark	Short	Absent	Absent	Absent	**Present**	Present	Absent
Celebes form	Sulawesi	Pale	Long	Present on R_1	Present	Present	**Absent**	Present	Absent

*Christophers (1931) described two forms (a and b) of ssp. *simlensis* (as var. *simlensis*) in the northern Kashmir region of India. Pale fringe spots M_2 and M_{3+4} are absent in form a, which, as Christophers noted, "…somewhat closely approximates to var. *baileyi* and many males show a condition of the fringe which is indistinguishable from that in var. *baileyi*."

TABLE 2. Comparison of distributions and characteristics of pupae and larvae of recognized forms of the Gigas Complex. Sumatran forms are highlighted in pale gray. Apparent diagnostic features are in larger boldface type.

Taxon	Distribution*	Pupa, seta 5-IV.VII	Pupa, paddle, apex	Larva, seta 2-C	Larva, seta 3-C	Larva, seta 4-C	Larva, seta 1-P	Larva, pecten, large spines
An. baileyi	Bangladesh, Cambodia?, China, India, Laos, Myanmar, Nepal, Taiwan, Tibet, Thailand, Vietnam	Branched, about as long as seta 1	**Truncate**	Single, ≈ 0.3 length of head	Long, single	Usually single (1,2)	4–10 branches	8–11(9)
An. prachongae	Thailand	Branched, about as long as seta 1	Emarginate	Single, ≈ 0.3 length of head	Long, branched	Usually double (1–3)	3–8 branches	5–7(6)
An. gigas								
ssp. *crockeri*	Sabah, Malaysia	Branched, markedly longer than seta 1	Emarginate	Single, long, > 0.5 length of head	Long, 1–3 branches, usually at tip	Stout, usually single or bifid at tip	4–6 branches	?
ssp. *danaubento*	Sumatra	?	?	?	Long, branched	0.5–0.7 length of 3-C, single or few branches	7–9 branches	?
ssp. *formosus*	Philippines	Branched, distinctly shorter than seta 1	Emarginate	Single, occasionally split into two	Long, single or 2–6 branches	≈ 0.5 length of 3-C, 2–8 branches	5–10 branches	
ssp. *gigas*	India	?	?	Single	Long, 2–6 branches	≈ length of 3-C, single, sometimes branched	3–8 branches	6–8
ssp. *oedjalikalah*	Sumatra	?	?	?	Long, branched	≈ 0.5 length of 3-C, single or weakly branched	7–9 branches	?
ssp. *pantjarbatu*	Sumatra	?	?	?	?	≈ 0.5 length of 3-C, 3 or 4 branches)	8–10 branches	?
ssp. *refutans*	Sri Lanka	Single, almost as long as seta 1	?	?	Long, usually 2 or 3 branches, sometimes single	?	?	?
ssp. *simlensis*	Bangladesh, China, India, Nepal, Pakistan	Branched, about as long as seta 1	Slightly convex?	Single	Long, 2–5 apical branches, may be single	≈ 0.5 length of 3-C, 2–5 branches	?	?
ssp. *sumatrana*	Sumatra	?	?	Single	**Short, stout, forked**	3-branched	8 branches	?
Celebes form	Sulawesi	?	?	Single, sometimes forked or 3-branched at tip	Long, ≈ 0.8 length of 2-C, with 3–5 distal branches	≈ 0.5 length of 3-C, 3 or 4 branches	4–6 branches	5 or 6

*Based on assessment of available taxonomic literature, with careful consideration of information contained in composite descriptions of *An. gigas s.l.*

setae and cluster of brown scales among setae on dorsoanterior surface. Pleura with brown and pale horizontal bands, upper brown band on postspiracular area, upper mesokatepisternum and upper mesepimeron, median brown band on subspiracular area, area between upper and lower mesokatepisternal setae and mid to lower area of mesepimeron, lower brown band at level above coxae extending across mesokatepisternum, mesotrochantin, mesomeron and metameron; pleura without scales, with golden setae as follows: 9 upper proepisternal, 9 prespiracular, 11 or 12 prealar, 7 upper and 6 lower mesokatepisternal and 13–20 upper mesepimeral. *Wing* (Fig. 1A): Length 4.8–5.1 mm ($\bar{x}$= 4.9 mm), width 1.1–1.2 mm ($\bar{x}$= 1.2 mm); humeral crossvein without scales; pale scaling creamy white to yellow, dark scaling dark brown to nearly black, especially on costa, subcosta and vein R_1. Pattern of dark and pale spots as shown in Fig. 1A (cf. wing of *An. baileyi* in Fig. 1B); costa with long basal dark spot (about 0.3 mm), short humeral pale spot, long presector pale spot and distinct subcostal and apical pale spots; preapical pale spot absent on costa and vein R_1, weakly to distinctly developed on vein R_2; veins R_1 and R_2 with apical pale spots adjoining apical pale spot on costa; apices of veins R_{4+5}, M_1 and M_2 with pale scales adjoining pale fringe spots, vein M_{3+4} with few inconspicuous apical pale scales and sometimes an adjoining faint pale fringe spot; pale fringe spot absent between apices of veins 1A and CuA and apices of veins CuA and M_{3+4}; vein 1A with long pale spot on distal 0.5. *Halter*: Integument of scabellum pale; pedicel and capitellum dark-scaled. *Legs*: Mainly dark-scaled; coxae pale with pale setae; femora narrowly pale at base and less so at apex, midfemur with small dorsal preapical pale spot; tibio-tarsal and tarsal joints (*i.e.* apices and bases of tarsomeres) with narrow pale bands, pale scales less distinct or absent at bases of tarsomeres 4 and 5, tarsomere 5 pale at tip. *Abdomen*: Terga brown, sterna paler except basomedially; scales absent, setae golden.

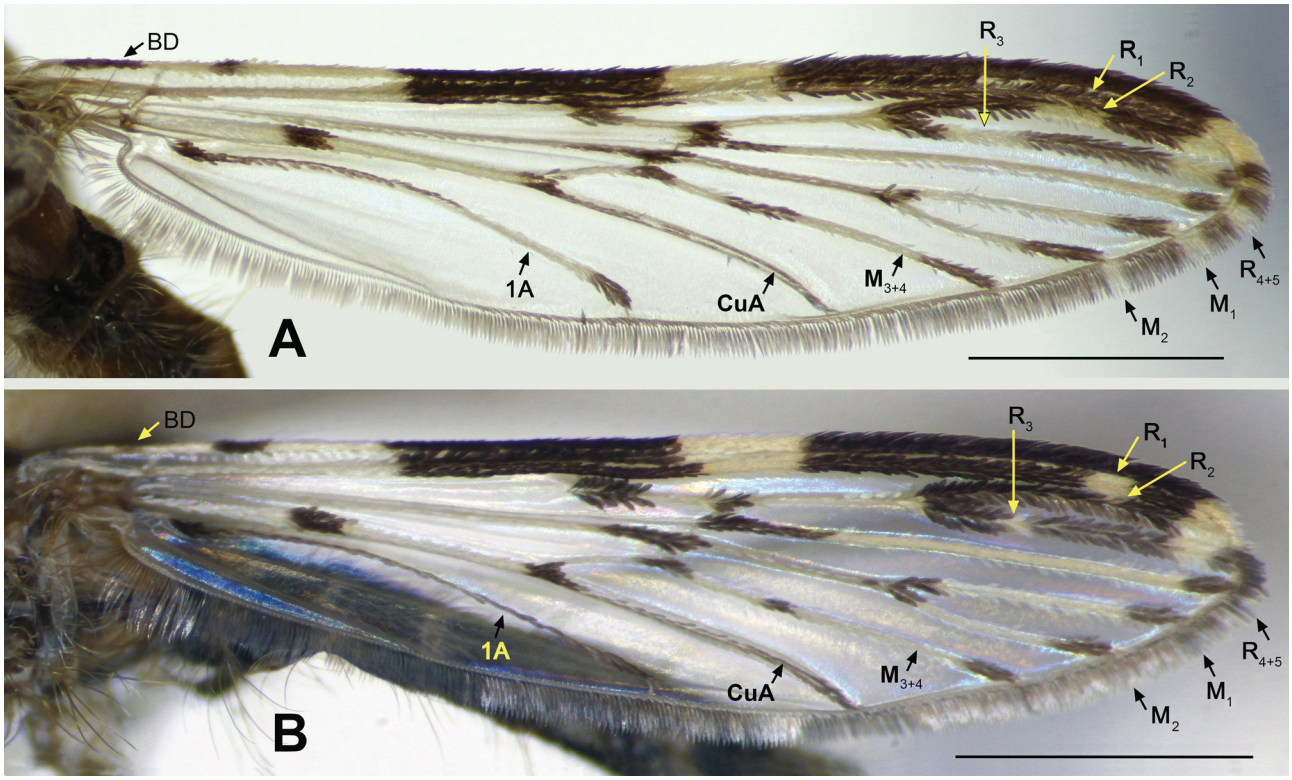

FIGURE 1. (A) Right wing of a female of *Anopheles prachongae*; (B) right wing of a female of *An. baileyi*. 1A, anal vein; BD, basal dark spot; CuA, anterior cubitus; M_1, M_2, M_{3+4}, medial veins; R_1, R_2, R_3, R_{4+5}, radial veins.

Male. Similar to female except as follows. *Head*: Proboscis longer, 2.8–3.3 mm ($\bar{x}$ = 3.1 mm), 1.4–1.6 length of forefemur. Maxillary palpus with dark brown and light yellow scales; with pale band at junction of palpomeres 2 and 3, apex of palpomere 3 with long dark scales and tuft of long golden setae on either side of mesal surface; club constricted between palpomeres 4 and 5; lateral surface of palpomere 4 largely pale-scaled, mesal surface with dense covering of long golden setae; proximal 0.25 and distal 0.5 of palpomere 5 pale-scaled, setae rather inconspicuous. *Wing*: Scaling of veins posterior to radius reduced; preapical pale spot fully developed on costa and veins R_1 and R_2, increasingly longer from costa to vein R_2. *Genitalia* (Fig. 2C): Tergum IX not strongly sclerotized,

relatively indistinct, lateral lobes widely separated by very narrow interlobar bridge, bridge nearly obsolete in middle. Gonocoxite with 2 parabasal setae at base of dorsomesal surface (pre-rotation sense), lateral parabasal long, relatively slender and acutely tapered, mesal parabasal 0.67 length of lateral parabasal, stout, distally flattened and apically hooked; lateral and ventral surfaces of gonocoxite with numerous very long setae (about length of gonocoxite), much shorter setae on dorsomesal and ventromesal surfaces (shorter than width of gonocoxite), dorsolateral surface with long slender scales among long setae, scales longer toward apex of gonocoxite, apices of some scales distinctly truncate; internal seta on middle of ventromesal surface similar but slightly thinner and distinctly longer than lateral parabasal seta, occasionally 2 internal setae present; gonostylus long, about 1.3 length of gonocoxite, slender, curved, slightly broader at base, ventromesal margin with complete line of minute setae, proximal 0.3 of ventrolateral surface with patch of minute spicules; gonostylar claw short, pigmented, inserted on dorsal side of apex, gonostylus with a short seta inserted proximal to base of claw. Ventral lobe of claspette with 3–6 relatively long simple setae; dorsal lobe of claspette with 4 flattened mesally curved setae. Aedeagus distinct, strongly sclerotized, length about 0.11 mm, bearing 5 or 6 pairs of apical leaflets, longest leaflet 0.025 mm, edge of leaflets without serration or serration unapparent; proctiger membranous, highly aculeate; ventrolateral paraprocts faintly sclerotized but distinctly demarcated.

TABLE 3. Salient anatomical differences that distinguish the adults, pupae and fourth-instar larvae of *Anopheles prachongae* and *An. baileyi*.

Character	*An. prachongae*	*An. baileyi*
Adults		
Wing, costa, basal dark spot	Long	Short
Wing, vein R_{4+5}, apex	Pale	Dark
Wing, R_{4+5} pale fringe spot	Present	Absent
Wing, vein M_1, apex	Pale	Dark
Wing, M_1 pale fringe spot	Present	Absent
Wing, vein M_2, apex	Pale	Dark
Wing, Vein 1A (anal vein)	Long pale spot on distal 0.5	Entirely dark-scaled
Male genitalia		
Tergum IX	Indistinct, weakly sclerotized	Distinct, strongly sclerotized
Tergum IX, interlobar bridge	Very narrow	Broad
Aedeagus, length	~ 0.10 mm	~ 0.15 mm
Aedeagus, leaflets, length	25 µm (0.025 mm)	45 µm (0.045 mm)
Pupae		
Setae 10,11-II	Absent	Usually present
Seta 9-VI	Normally straight	Normally bent
Paddle, apex	Emarginate	Truncate
Fourth-instar larvae		
Seta 3-C	3–6(3) branches	Single
Seta 12-T	Single	2,3(2) branches
Seta 1-II	1–5(4) branches	6–11(6) branches
Seta 1-III–VII, sum of branches on one side	83–119 ($\bar{X}$ = 110)	122–148 ($\bar{X}$ = 131)
Pecten, large spines	5–7(6)	8–11(9)
Seta 1-X, insertion	In notch at edge of saddle	On margin of saddle
Anal papillae, length	0.80–1.41 mm ($\bar{X}$ = 1.04 mm)	0.55–0.65 mm ($\bar{X}$ = 0.60 mm)

Pupa (Fig. 2A,B). Character and positions of setae as figured; numbers of branches in Table 4 (cf. chaetotaxy of *An. baileyi* in Table 5). *Cephalothorax*: Lightly to moderately pigmented, with patches of darker pigmentation especially around bases of maxillary palpi, lateral areas of scutum on either side of median keel and metathoracic wings. Maxillary palpus of female (length ~ 0.85 mm) shorter than palpus of male (length about 1.0 mm). Setae normally all single, setae 1,5,7,8-CT occasionally split at apex; seta 7-CT short, about same length as seta 6-CT. *Trumpet*: Laticorn, moderately pigmented, large, transverse length from meatal cleft to apex of pinna 0.46–0.55 mm ($\bar{x}$ = 0.53 mm), without secondary cleft and tragus, rim thin and uniform, without tracheoid area at base. *Abdomen*: Length 3.5–4.2 mm ($\bar{x}$ = 4.0 mm); lightly to moderately pigmented with variable patches of darker pigmentation especially on anterolateral areas of terga. Seta 0-II–VIII single, inserted anterior and slightly mesad of seta 2; seta 1-III–VII shorter than following tergum, 1-II,IV usually multi-branched, 1-V (usually) and 1-VI,VII single, 1-IX minute, usually double (1–3 branches); seta 5-IV–VII branched, nearly as long as seta 1; seta 7-VI distinctly longer than 7-VII (also in *An. baileyi*); seta 8-III–VII inserted on mesal side of fold line; seta 9-II–VII progressively longer and transforming from peg-like and straight to acutely spine-like and inwardly bent on succeeding posterior terga, generally shorter than corresponding seta in *An. baileyi* (Table 5), 9-VIII with strong central stem and 15–17(15) lateral branches. *Genital lobe*: Moderately tanned; male – length about 0.5 mm; female – length about 0.3 mm, distal and lateral margins of ventral surface distinctly spiculate. *Paddle*: Lightly pigmented, buttress and base of midrib slightly darker; asymmetrical, outer part larger than inner part, apex emarginate; length 0.93–1.21 mm ($\bar{x}$= 1.10 mm), width 0.66–0.82 mm ($\bar{x}$ = 0.75 mm), index 1.39–1.54 ($\bar{x}$ = 1.46), outer margin with minute serration extending approximately 0.4–0.7 from base; refractile border about 0.7 length of paddle, proximal part without serration. Seta 1-Pa inserted at base of apical emargination, single, generally stiff and straight, length < 0.1 length of paddle length; seta 2-Pa minute, inconspicuous.

Larva, fourth-instar (Fig. 3). Character and positions of setae as figured; numbers of branches in Table 6 (cf. chaetotaxy of *An. baileyi* in Table 7). *Head*: Length ~ 0.8 mm, very slightly wider than long; lightly pigmented with variable darker patches around bases of setae 5,6-C and posteriorly on dorsal apotome and lateralia; collar and dorsomentum darkly pigmented. Seta 2-C close-set, separated at base by less than width of alveolus, long, single; seta 3-C shorter than 2-C, with 3–6(3) short branches on distal 0.5; seta 4-C small, usually 2-branched at mid-length (1–3); setae 5–8,11,13-C plumose; seta 9-C not plumose, with 3–6(6) branches (usually 5 or 6). *Antenna*: Lightly pigmented; entirely spiculate; length 0.32–0.36 mm ($\bar{x}$ = 0.34 mm). Seta 1-A inserted about 0.3 from base of antenna, relatively long, about 0.35 length of antenna, with 5–10(8) branches; seta 4-A longer than seta 1-A, about 0.45 length of antenna, with 5–12(6) branches. *Thorax*: Integument hyaline, smooth. Seta 1-P branched distally, with 3–8(5) branches; seta 2-P somewhat plumose, with 8–12(10) branches, borne in sclerotized tubercle; setae 1,3-P not borne on tubercles; setae 4,5,7,8,14-P, 1,8,14-M and 5,7,8-T plumose; seta 6-M large, usually 2- or 3-branched (1–5), branches arise well beyond base; seta 7-M often 2-branched (1–3) near mid-length; seta 3-T with 5–9(7) slender branches; setae 9,10,12-T single; seta13-T usually double or triple, sometimes single. *Abdomen*: Integument hyaline; ventral surface of all segments with minute spicules. Anterior tergal plates on segments I–VIII, about 0.2 width of segment, distinctly smaller on segment II and notably larger on segment VIII; median accessory tergal plates present on segments III–VII, present or absent on segment II; submedian accessory tergal plates absent. Seta 1-I,II not palmate, similar to seta 3-T but 1-II with longer main stem and 1–5(4) branches, 1-III–VII fully palmate (Fig. 3), with 33–54 leaflets, leaflets entirely dark, acuminate, with smooth or weakly notched edges, without shoulders and filament; setae 6,7-I,II and 6-III large and plumose, 6-IV,V long, 6-IV usually 2-branched (1–3), 6-V normally single, occasionally double, 6-VI usually single (1–4 branches), about 0.5 length of 6-IV,V. Pecten plate moderately pigmented, with 5–7(6) long spines and 12–15(14) short spines (in pattern of variable numbers of alternating large and small spines), total number of spines 18–22(19). Saddle lightly pigmented with darker borders and relatively strong spicules on posterolateral margins, length 0.39–0.43 mm ($\bar{x}$ = 0.40 mm). Seta 1-X longer than saddle, inserted in notch at edge of saddle; seta 3-X with apically hooked branches; seta 4-X (ventral brush) with 9 offset pairs of setae with branches arising noticeable distance from grid, most anterior of 4a-X about 0.6 length of longest setae (4c–g-X), with 11–13 branches, most posterior of 4i-X shorter, 0.4–0.5 length of longest setae, with 5–8 branches, setae 4b–h-X with 11-15 branches, longest branches 0.6–0.7 length of seta. Anal papillae very long, about 3 times length of saddle, 0.80–1.41 mm ($\bar{x}$= 10.4 mm).

Etymology. We are very pleased to name this species in honor of our good friend and colleague Mrs. Prachong Panthusiri, who produced an extraordinary number of beautiful mosquito illustrations for numerous publications while working for the Southeast Asian Treaty Organization (SEATO) and the successional Armed Forces Research Institute of Medical Sciences (AFRIMS) laboratories in Bangkok.

TABLE 4. Numbers of branches for setae of pupae of *Anopheles prachongae* (5 specimens). Modes in parentheses.

Seta	Cephalothorax	Abdominal segments									Paddle
No.	CT	I	II	III	IV	V	VI	VII	VIII	IX	Pa
0	–	–	1	1	1	1	1	1	1	–	–
1	1	~80	1–3(2)	1–5(4)	2–5(3)	1,2(1)	1	1	–	1–3(2)	1
2	1,2(1)	2,3(3)	4,5(4)	3,4(3)	2	2	2	2	–	–	1
3	1	1–4(2)	1,2(1)	1	1–3(2)	1	1	1	–	–	–
4	1	2,3(3)	1–3(3)	1–4(2)	1–3(2)	1,2(2)	1	1	1	–	–
5	1,2(1)	2,3(2)	2,3(3)	4–6(5)	4–9(5)	4–6(5)	3–7	3–5(3)	–	–	–
6	1	1	1	1	1	1	1	1,2(1)	–	–	–
7	1,2(1)	1–3(2)	1,2(1)	1–3(2)	1–3(2)	1,2(2)	1	1	–	–	–
8	1,2(1)	–	–	1,2(2)	1,2(1)	1,2(1)	1,2(1)	1–3(1,2)	–	–	–
9	1	1	1	1	1	1	1	1	15–17(15)	–	–
10	1,2(1)	–	–	1	1	1	1,2(1)	1	–	–	–
11	2–4(2)	–	–	1,2	1	1	1	1	–	–	–
12	2–4(3)	–	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–	–
14	–	–	–	1	1	1	1	1	1	–	–

TABLE 5. Numbers of branches for setae of pupae of *Anopheles baileyi* (4 specimens). Modes in parentheses.

Seta	Cephalothorax	Abdominal segments									Paddle
No.	CT	I	II	III	IV	V	VI	VII	VIII	IX	Pa
0	–	–	1	1	1	1	1	1	1	–	–
1	1,2(2)	~70	3–5(3)	2–6(3)	2,3	1	1	1	–	2,3(3)	1
2	1,2(1)	3–5(3)	3,4(4)	3–5(3)	1–3(2)	2	2	1,2(2)	–	–	1
3	1,2(2)	1–3(1)	1,2(1)	1,2	3,4	1,2(1)	1	1,2(1)	–	–	–
4	1,2(2)	3,4(3)	2,3(2)	2,3(3)	1–4(1,3)	1,2(2)	1	1	1	–	–
5	1–3(2)	1,2(2)	2–4(3)	4–7(6)	4,5(5)	3–6(6)	4–7(6)	4–7(5)	–	–	–
6	1	1,2(1)	1,2	1–3(2)	1	1	1	1,2(2)	–	–	–
7	1,2(1)	1,2(2)	1,2(2)	2–5(2)	2–4(2,3)	1,2	1	1,2)1)	–	–	–
8	1,2(1)	–	a–2*	1–3(2)	1,2	1	1,2(1)	1–3(2)	–	–	–
9	1	1	1	1	1	1	1	1	11–15	–	–
10	1–4(1)	–	0,2(2)†	2	1	1	1	1,2(1)	–	–	–
11	2,3(3)	–	0–2(1)‡	1,2(1)	1	1	1	1	–	–	–
12	2,2(2)	–	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–	–
14	–	–	–	1	1	1	1	1	1	–	–

*Alveolus only or single or 2-branched seta.
†Usually present.
‡Usually present; usually single when present.

TABLE 6. Numbers of branches for setae of larvae of *Anopheles prachongae* (7 specimens). Modes or most common numbers of branches in parentheses; means in square brackets, rounded to nearest whole number.

Seta	Head	Thorax			Abdominal Segments								
No.	C	P	M	T	I	II	III	IV	V	VI	VII	VIII	X
0	1	1	–	–	–	1,2(1)	1,2(1)	1,2(2)	1,2(1)	1,2(1)	1	1,2(1)	–
1	1	3–8(5)	21–30[25]	1–4(1)	3–6(4)	1–5(4)	17–28[23]	18–26[22]	16–27[23]	17–28[22]	11–23[20]	1	1
2	1	8–12(10)	1–6(1)	1	4–8(5,6)	6–9(8)	4–6(5)	4–8(5,6)	4–7(5)	3–8(4)	4–6(4)	8–10(9)	11–18(15)
3	3–6(3)	1,2(1)	1	5–9(7)	1,2(1)	1	1	1	1	1	2–5(3)	6–10(9)	8–11(9)
4	1–3(2)	18–24[21]	1–4(2,3)	2–4(3)	3–6(5)	4–7(5)	3–5(3)	2–4(3)	124(3)	1	1,2(1)	1	9 pair
5	11–15(13)	28–41[37]	1	24–34(26)	3–5(5)	6–12(7,9)	5–9(6)	3–5(3)	3–5(4)	3–6(5)	5–7(5)	4–6(5)	–
6	11–15(15)	1	1–5(2)	1,2(2)	18–24(21)	18–32[23]	13–19(15)	1–3(2)	1,2(1)	1–4(1)	2–6(5)	–	–
7	13–17(15)	25–34(28)	1–3(2)	17–26(24)	12–27(16)	16–24[20]	2–5(3)	3	3	2–7(2)	2–7(6)	1–S,	3–5(4)
8	6–10(8,9)	20–27(24)	18–34[25]	18–25(22)	–	1	1,2(1)	1	1,2(2)	1,2(2)	3–7(4)	2–S,	3–6(6)
9	3–6(5,6)	1	1	1	6–9(7)	7–12(10)	6–11(9)	5–9(8)	6–11(8)	5–9(8)	4–9(5)	6–S,	2–5(4)
10	1,2(2)	1	1	1	1	1–3(3)	1	1	1	1,2(2)	3–5(4)	7–S,	1,2(1)
11	29–45[35]	2–5(3)	1,2(1)	1,2(1)	2–4(3)	1	2,3(2)	2,3(2)	2,3(2)	1–3(2)	1–3(1)	8–S,	4–8(5)
12	2,3(3)	1	1	1	1–3(3)	1	1–3(2)	2,3(2)	1–3(2)	1,2(1)	1	9–S,	3–6(5)
13	11–17(12)	6–11(9)	5–9(7)	1–3(3)	3–6(5)	4–8(6)	3–8(6)	2–4(3)	3,4(3)	5–10(7)	2,3(3)	–	–
14	4,5(5)	6–14(10)	5–9(8)	–	–	–	1	1	1	1	1	1	–
15	2–7(5)	–	–	–	–	–	–	–	–	–	–	–	–

TABLE 7. Numbers of branches for setae of larvae of *Anopheles baileyi* (5 specimens). Modes or most common numbers of branches in parentheses; means in square brackets, rounded to nearest whole number.

Seta	Head	Thorax			Abdominal Segments								
No.	C	P	M	T	I	II	III	IV	V	VI	VII	VIII	X
0	1	1	–	–	–	1	1,2(1)	1	1,2	1	1	1	–
1	1	4–10(6)	20–28[25]	1	3–6(3)	6–11(6)	21–32[26]	25–33[28]	24–34[30]	23–31[27]	19–25[22]	1	1
2	1	11–17(14)	1–3(1,3)	1	3–6(3)	5–9(5)	4–7(6)	4–6(5)	3–6(5)	3–6(4)	4–6(4)	5–9(5)	14–16(14)
3	1	1	1	7–15(8)	1,2(1)	1	1	1	1	1	2–4(3)	7–11(10)	5–9(8)
4	1,2(1)	18–31[24]	2	1–4(3)	5–8(6)	3–5(4)	2–4(4)	2,3	2–4(3)	1	1	1	9 pair
5	12–16(13)	32–53[41]	1	28–35(28)	4–8(5)	7,8(8)	4–7(6)	3–5(4)	3–5(5)	5–7(5,6)	6–9(7,8)	4–7(5,6)	–
6	18–21(15)	1	3,4(3)	1,2	18–22(20)	20–29[23]	13–24(15)	1,2(2)	1	2	2–4(3)	–	–
7	16–18(16)	25–36(28)	1,2(2)	21–32(21)	15–23(20)	19–29[23]	3–4(3)	2–4(3)	2,3(3)	2,3(3)	4–6(4,6)	1–S,	4–7(4,5)
8	8–12(9)	20–28(26)	13–24[18]	21–28(21)	–	1,2(2)	1,2(1)	1,2(2)	2,3(2)	2,3(2)	4,5(4)	2–S,	4–6(4,5)
9	9–11(10)	1	1	1	4–9(6)	7–13(7)	5–10(8,9)	5–9(7)	4–7(5,6)	5–7(6,7)	1–4(3)	6–S,	2–4(3)
10	2	1	1	1	1	1–3(2)	1	1	1	2	3–6(3,5)	7–S,	1,2(2)
11	20–32[27]	2–4(3)	1,2(1)	1	3,4(3)	1	1,2(2)	1,2(2)	2,2(2)	1,2(2)	1	8–S,	2–4(3)
12	2–5(5)	1	1	2,3(2)	2,3(3)	1	1,2(2)	1–3(2)	1,2(2)	1	1	9–S,	3–4(3)
13	7–13(9)	4–6(5)	4–8(6)	2	2–6(4)	5–8(6)	5–10(7)	3,4(3)	3–5(3)	6–10(6)	2–4(3)	–	–
14	?	6–10(7)	6–9(7)	–	–	–	1	1	1	1	1	1	–
15	4–6(4)	–	–	–	–	–	–	–	–	–	–	–	–

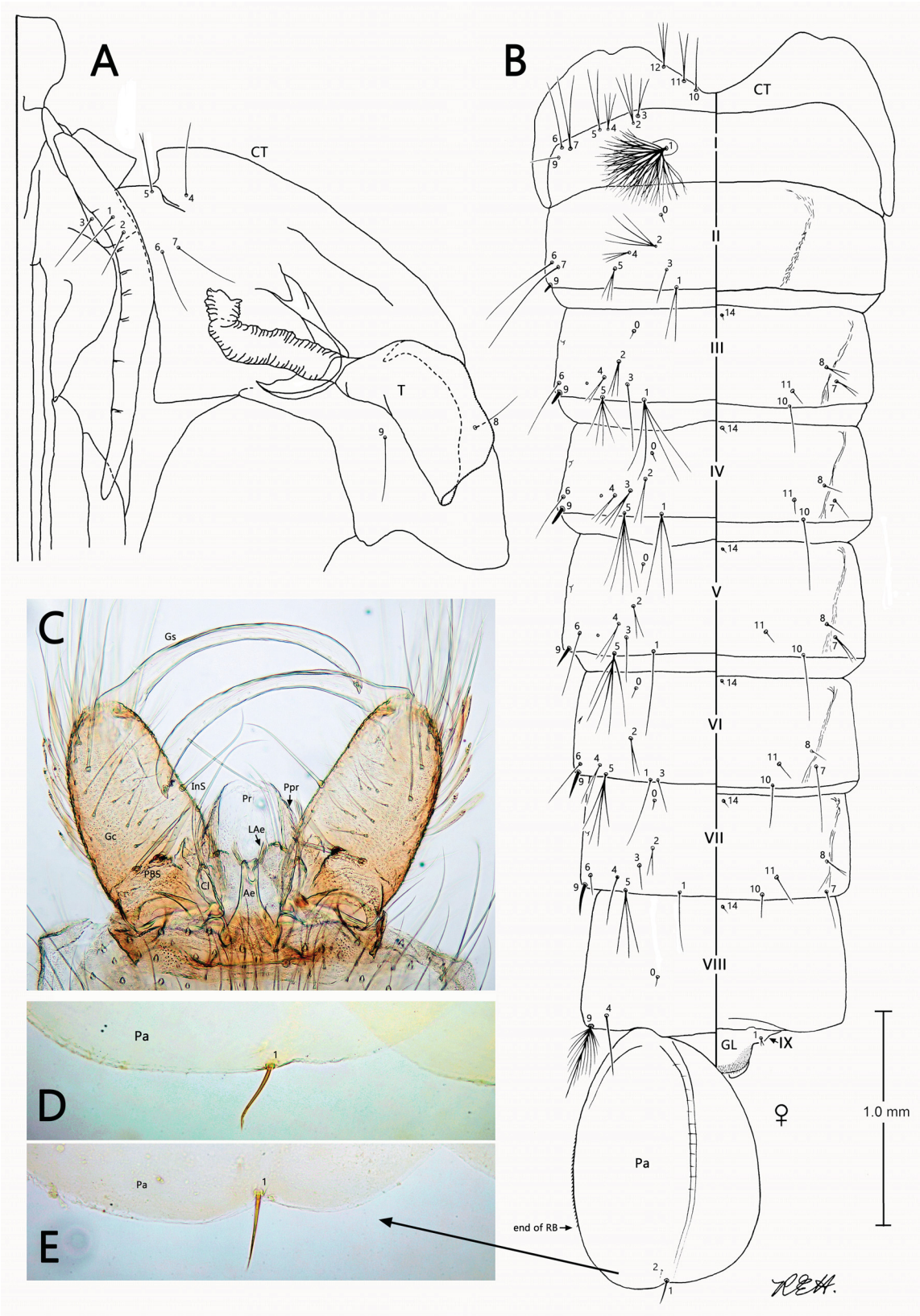

FIGURE 2. (A–C, E) *Anopheles prachongae*: A, pupa, left side of cephalothorax, dorsal to right; B, pupa, dorsal (left) and ventral (right) aspects of metathorax and abdomen; C, male genitalia, dorsal (tergal) aspect (note presence of two internal seta on left gonocoxite); E, apex of paddle. (D) Apex of paddle of *An. baileyi*. Ae, aedeagus; CL, claspette; CT, cephalothorax; Gc, gonocoxite; Gs, gonostylus; InS, internal seta; LAe, leaflets of aedeagus; Pa, paddle; PBS, parabasal setae; Ppr, paraproct; Pr, proctiger; RB, refractile border; I–IX = abdominal segments I–IX; 1–14 = setal numbers for specified areas, *e.g.* seta 3-I.

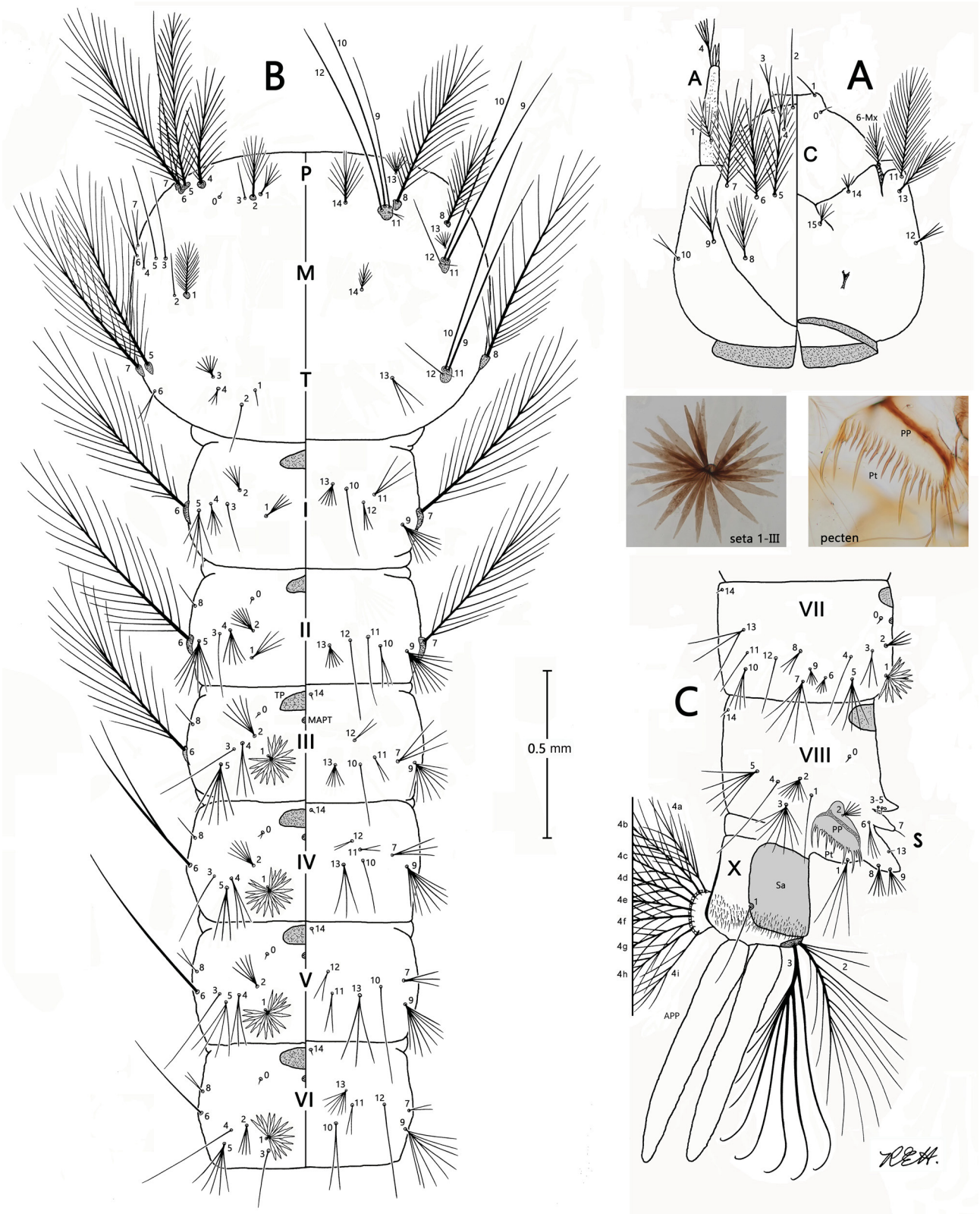

FIGURE 3. Fourth-instar larva of *Anopheles prachongae*. A, Head, dorsal (left) and ventral (right) aspects of left side. B, Thorax and abdominal segments I–VI, dorsal (left) and ventral (right) aspects of left side. C, Abdominal segments VII–X, left side. A, antenna; APP, anal papilla; C, cranium; P, prothorax; PP, pecten plate; Pt, pecten; M, mesothorax; MAPT, median accessory tergal plate; S, spiracular lobe; Sa, saddle; T, metathorax; TP, tergal plate; I–VIII,X = abdominal segments I–VIII and X; 1–15 = setal numbers for specified areas, *e.g.* seta 5-C.

Bionomics. Like the other forms of the Gigas Complex, *An. prachongae* is a montane species. The immature stages which gave rise to the type series (see below) were collected at an elevation 1,420 m. Immature stages have been collected from stream-pool, stream-margin, seep or seepage-spring and rock-hole habitats (Rattanarithikul *et al*., 2006).

Distribution. *Anopheles prachongae* is only known from its type locality in the Phetchabun Mountain Range in Loei Province of northern Thailand, bordering Sainybuli and Vientiane Provinces of Laos. The Phetchabun Range consists of two parallel mountain chains in Chaiyaphum, Loei, Phetchabun and Phitsanulok Provinces of Thailand. The chains are a southern extension of the Luang Prabang Range that mainly encompasses Sainyabuli Province of northwestern Laos and Nan and Uttaradit Provinces of northern Thailand. Elevations above 1,000 m are covered by evergreen forest, to the height of the highest mountain in the range, Phu Soi Dao, with an altitude of 2,120 m. Since the type specimens of *An. prachongae* were collected at an altitude of 1,420 m, the species is likely to be found in ecologically similar areas within the Luang Prabang Range.

Specimens examined. *Anopheles prachongae—Holotype*, ♀ (TH 976-27), with LePe on microscope slide: THAILAND, *Loei Province*, Phu Luang District, Huai Pong (17° 7′ N 101° 32′ E), elevation 1,420 m, 11 Jan 1989, stream pool, coll. Rampa *et al*. *Paratypes*, same data as holotype: 1♀ (TH 968-12) with LePe on microscope slide; 2♂ (TH 970-11; TH 976-36) both with LePe and dissected genitalia on separate microscope slides; 1♂ (TH 976-52) with LePe on microscope slide; 2L (TH 970-C; TH 976-D) on individual microscope slides. The type series is deposited in the National Museum of Natural History (USNM), Smithsonian Institution, Washington, DC. *Anopheles baileyi*—2♀ (TH 161-31; TH 161-63) with LePe on microscope slides, 1♂ (TH 161-46) with LePe and dissected genitalia on separate microscope slides, 1♂ (TH 161-111) with Pe and dissected genitalia on separate microscope slides; 1L (TH 161-D) on microscope slide: THAILAND: *Chiang Mai Province*, Amphoe Chom Tong, Doi Inthanon, sphagnum bog (18° 35′ N 98° 29′ E), elevation 2,540 m, 23 Apr 1981, coll. Harrison; 1L (TH 214-I) on microscope slide, same locality as TH 161, 30 Mar 86, coll. Rampa & team. These specimens are also deposited in the USNM.

Discussion

Members of the Gigas Complex occur in mountainous areas in the Oriental Region, the Manchurian Subregion of the Palaearctic Region and the Austro-Malayan Subregion of the Australasian Region. All forms of the complex are recorded from altitudes at or usually above 1000 m (Christophers, 1933; Kundig, 1934; Bonne-Wepster & Swellengrebel, 1953; Colless, 1955). Most of the subspecies of *An. gigas* are known only from specific or limited geographic areas, and whether all are truly allopatric and morphologically distinct is unknown. Their true status cannot be determined until significantly more material is available from many localities for comparative study, especially the larval and pupal stages. At present, the currently recognized forms are distinguished principally on the presence and absence of pale markings on the wings of adult females (Table 1), and to a lesser extent on a few select setal characters of the known larval and pupal stages (Table 2). Based on the data shown in Tables 1, 2 and 3, we observe that *An. baileyi*, *An. gigas* and *An. prachongae* are distinct species; however, it is unlikely that all of the Sumatran forms of *An. gigas* (highlighted in pale gray in Tables 1 and 2), known only from their type localities, represent separate subspecies. There seems little doubt that *An. gigas sumatrana* is a distinct entity as it is the only form of the complex in which larval seta 3-C is short, stout and forked and the wings of the adults have a pale fringe spot between the tips of veins CuA and M_{3+4} (characters highlighted in grey in Tables 1 and 2). In fact, based on these two unique (diagnostic) characteristics, as well as the combination of three other characters of females, *i.e.* apex of maxillary palpus dark, pale fringe spot present between the apices of veins CuA and M_{3+4} and absent between the apices of veins 1A and CuA, we are compelled to hereby formally recognize *sumatrana* as a distinct species of the complex. On the other hand, the available data do not support the separate subspecific status of *danaubento*, *oedjalikalah* and *pantjarbatu*. Further collection and study of Sumatran specimens may reveal that these three nominal forms represent a single entity. If this proves to be the case, then *danaubento* has priority over the other two names.

We also question the taxonomic status of the other subspecies of *An. gigas*, which exhibit distinct combinations of morphological characters (Table 1, except *simlensis* which is diagnosed by the presence of a preapical pale spot on the costa) and have, as far as known, allopatric distributions (Table 2): *crockeri* occurs in Borneo, *formosus* in

the Philippines, *refutans* in Sri Lanka and *simlensis* in northern areas of south-central Asia. It is noteworthy that Christophers (1931) encountered two forms of *simlensis* in the northern Kashmir region of India based on the presence/absence of fringe spots at the apices of veins M_2 and M_{3+4} (see Table 1 and Christophers, 1933). The nominotypical member of the Gigas Complex, currently denoted as subspecies *An. gigas gigas*, occurs in southwestern India. The combination of morphological data and allopatric isolation would seem to support the recognition of these nominal taxa as separate species, and the unnamed form in Sulawesi, the Celebes form of Kundig (1934), could also be a distinct species, but it seems prudent to continue to rank them as subspecies pending further study, with emphasis on the immature stages. It must be emphasized that *An. gigas*, *i.e.* the nominotypical member of the complex, will remain a valid species regardless of what discoveries are made concerning the status of the geographical forms that are currently recognized as subordinate taxa of this species.

Speciation of montane fauna can take place across elevation gradients and within or between mountain ranges (e.g. Willmott *et al*., 2001; Hall, 2005). Species that have evolved to utilize habitats at cooler higher elevations generally have fragmented distributions; thus, many montane species are endemic to certain mountain ranges. This suggests that the evolutionary history of the Gigas Complex has been shaped primarily by upward adaptation to higher elevations. If so, it seems plausible that the ancestor of the Gigas Complex adapted to the cooler temperate conditions of mountainous terrain prior to the repeated formation and disappearance of land bridges between the mainland and islands of Southeast Asia that occurred during the Pleistocene, from 0.01–2.6 million years ago (mya). The increasing isolation and adaptation of populations to climatic conditions of higher altitudes resulted in restricted gene flow, or the cessation of gene flow between forms confined to islands. The problem with this scenario is that there are no species obviously related to the Gigas Complex at elevations below 1000 m, but perhaps members of the complex have undergone little morphological differentiation while ancestral forms diversified at lower elevations, which is connoted by pre-Pleistocene speciation events within subgenus *Cellia* during the early and mid-Pliocene from 3.2–4.5 mya (Morgan *et al*., 2009). It is interesting to note that Reid (1968) suggested subgenus *Cellia* may have arisen from an ancestral form that resembled a species like *Anopheles gigas*. Similarities in the ornamentation of the wings and legs suggest that members of the Gigas Complex may be nearer to the ancestral form that gave rise to subgenus *Cellia*.

As noted in the description, males of *An. prachongae* occasionally have two internal setae on the ventromesal margin of the gonocoxite (see left gonocoxite in Fig. 2C). This unusual condition is noteworthy because as far as known only a single internal setae is present in other species of subgenus *Anopheles*.

This is the first time that the larval and pupal stages of members of the Gigas Complex have been studied in detail, and fully illustrated in the case of the new species described above. The information presented herein will hopefully set the stage for further study and changes in the taxonomy of the Gigas Complex. Many potentially useful larval and pupal characters, as well as finer details of the male genitalia, remain to be investigated in most members of the complex, but it seems likely that such characters, especially if coupled with DNA sequence data, are needed to elucidate and delimit independent lineages within the complex.

Finally, we take this opportunity to point out that the mosquito fauna of Thailand is more completely known than for any other tropical country. In 2010, 459 species were known to occur in Thailand (Rattanarithikul *et al*., 2010). Since then a total of seven new species, including *An. prachongae*, have been described from Thailand. The six other species include *An*. (*Cellia*) *rampae*, a species in the Maculatus Group (Somboon *et al*. 2011); *Nyctomyia pholeocola*, a cavernicolous species of tribe Aedini (Harbach *et al*. 2013), originally placed in genus *Nyx*, preoccupied (Harbach, 2013); *Nc. biunguiculata* (Harbach & Taai (2014); *An*. *dissidens*, *An*. *saeungae* and *An*. *wejchoochotei*, three species in the Barbirostris Complex of subgenus *Anopheles* (Taai & Harbach (2015). This brings the total number of species known to occur in Thailand to 466—remarkably representing 13% of the currently recognized species of Culicidae.

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